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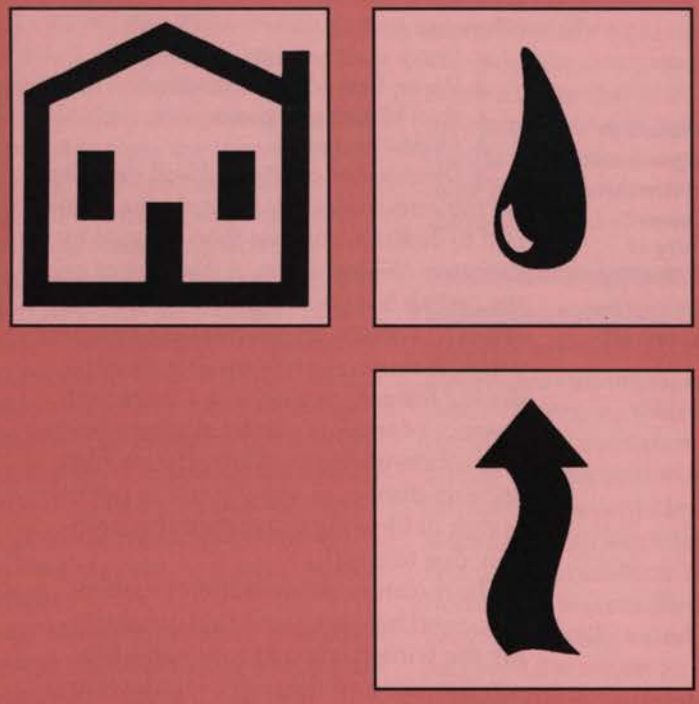
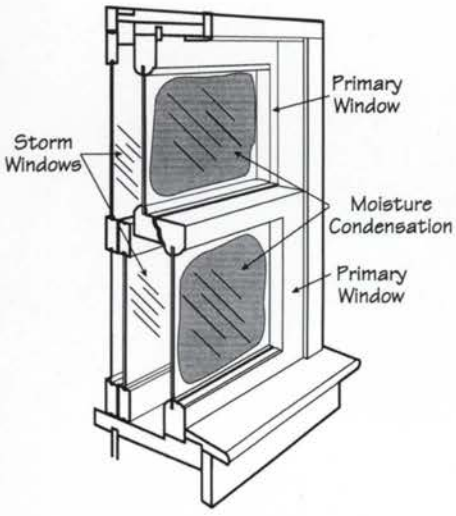
# Moisture Condensation



**Council Notes** **Volume 13, Number 1**
Building Research Council College of Fine and Applied Arts – University of Illinois

*This publication will describe the causes of excess moisture, how condensation occurs, and methods used to correct moisture problems.*

***The information contained in this publication was produced by the School of Architecture—Building Research Council (BRC) at the University of Illinois at Urbana-Champaign. For more information, or a free publications catalog, call 217-333-1801.***




***Windows or storm windows may sometimes have frost in cold weather.***

Remember putting pots of water on radiators to add humidity to the air in winter? This was a common practice in the days when homes were built with wood board sheathing and sometimes no insulation. Today, builders use panel products for sheathing, and walls and ceilings that are insulated. Houses are "tight" and prone to moisture problems rather than difficulties with dryness.

*Excessive humidity can cause a number of undesirable conditions—some obvious and others less evident:*

- Damp spots on walls or ceilings
- Water, frost or ice on windows
- Paint blistering or peeling
- Mildew and mold
- Deterioration of attic and wall sheathing

Problems caused by leaks can be difficult to distinguish from those caused by moisture condensation. A damp spot on the ceiling is a good example. Observing when a problem occurs can help you pinpoint its cause. A problem that occurs during the cold season when there is an absence of snow is almost always a moisture condensation problem. If a problem appears during, or shortly after a period of rain or blowing snow, then it is probably due to a leak.

The moisture condensation problems discussed here are those that occur during the winter, when indoor humidity can condense on the walls, windows and attic areas. Moisture problems occur during summer, too, particularly in hot humid climates, but these problems will not be covered in this circular.

## AIR AND MOISTURE

All air contains some water. The moisture content of air is generally given in terms of relative humidity. Most people can be comfortable breathing air that is dry, humid, or in between. If the air feels dry, it has a low relative humidity. Air that feels moist has a high relative humidity.

Warm air can hold more moisture than cold air. If the relative humidity of air is 50 percent, then that air is holding half the amount of water vapor it *could* hold at that temperature. There are two ways to increase relative humidity: add humidity, or cool the air. Relative humidity can be lowered by removing water from the air, or by heating the air.

Relative humidity is the most common way to measure and discuss humidity in homes. The moisture content of wood and other building materials will change, depending on the relative humidity of the surrounding air.

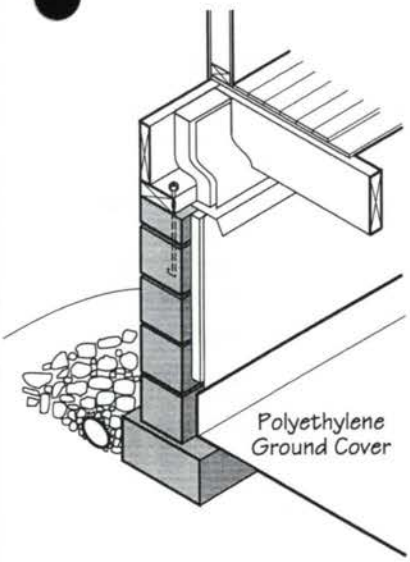
Another way to measure humidity in the air is to measure dew point temperature, which is independent of air temperature. Dew point temperature measures the absolute amount of water in the air. If air temperature is equal to the dew point temperature, the air is said to be at saturation, or 100 percent relative humidity.

Condensation occurs when moist air touches a surface colder than the dew point temperature of the air. If the cold surface is below freezing, condensation will appear as frost. Water or frost often appears on windows in cold weather. Window condensation that occurs at the beginning of the cold season and leaves a thin film of dew or frost on the window is normal. Windows are designed to withstand occasional light condensation.

However, condensation that occurs as running water, particularly on the inside surface of a double-pane window (sealed double glass or a single-pane plus storm sash), may be the first sign of a moisture problem. The best way to solve a moisture problem is to eliminate the source of excess moisture.

## REDUCING MOISTURE SOURCES

We release moisture into the air merely by following our daily routines. A family of four can release 10 pounds of moisture into the air just by cooking, showering, cleaning, and breathing. Homes are designed to exhaust stale air and provide fresh air. This prevents the accumulation of excess moisture. However, there are sources of moisture that overwhelm standard ventilation systems.




*A ground cover is essential in a crawl space.*

## GROUND WATER THROUGH THE FOUNDATION

Most homes with problems of excess moisture have wet basements or crawl spaces. Some researchers have estimated that as much as ten times the normal moisture production in a house can be contributed by a wet crawl space.

To keep basements and crawl spaces dry, the soil in contact with the foundation must be kept dry. See Building Research Council circular F13.1—*Gutters and Downspouts.*

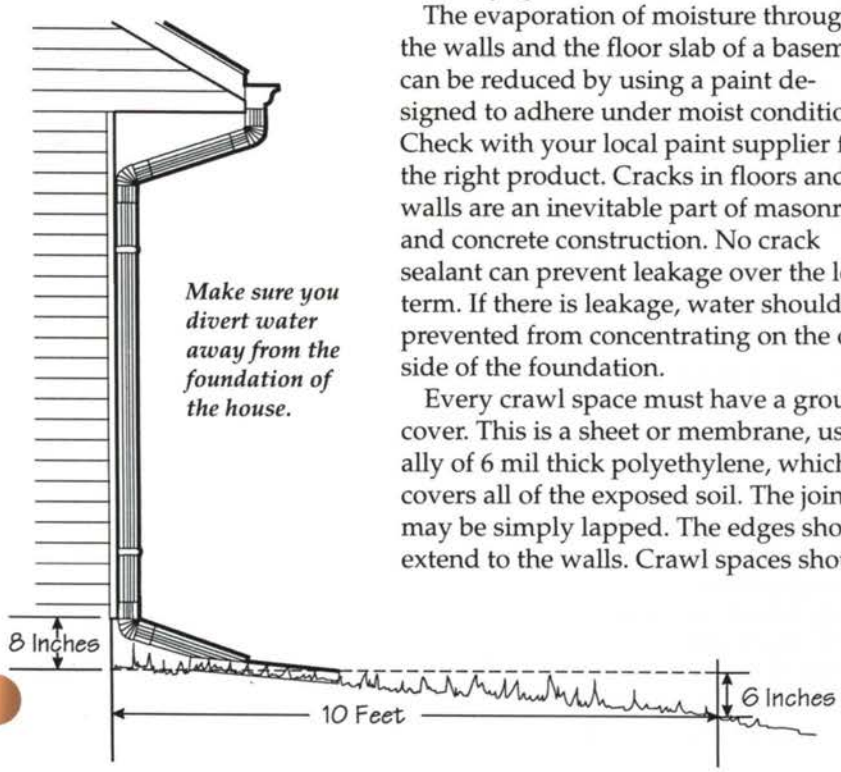
Any water that collects on the roof should be deposited onto the soil surface as far as possible from the foundation. Most building codes require that the first ten feet of soil extending outward from the house be pitched away from the house at a 5 percent grade, or 6" of fall in the first ten feet. This helps divert rainwater from the house. Splash blocks and extenders on the downspouts also help move water away from the foundation.

Many houses have footing tiles to collect water that accumulates at the base of the foundation. The water in a footing tile must go into a municipal storm water drainage system, to a sump pump, or to daylight.

The evaporation of moisture through the walls and the floor slab of a basement can be reduced by using a paint designed to adhere under moist conditions. Check with your local paint supplier for the right product. Cracks in floors and walls are an inevitable part of masonry and concrete construction. No crack sealant can prevent leakage over the long term. If there is leakage, water should be prevented from concentrating on the outside of the foundation.

Every crawl space must have a ground cover. This is a sheet or membrane, usually of 6 mil thick polyethylene, which covers all of the exposed soil. The joints may be simply lapped. The edges should extend to the walls. Crawl spaces should be inspected regularly (after every heavy rain, for example) to ensure water does not collect on top of the ground cover. Damp soil beneath the ground cover should have no ill effect on the house. Many building codes require vents in crawl spaces. Vents should not be thought of as the principal means of preventing moisture. This is achieved by good site drainage and a ground cover.

Slab foundations may allow evaporation of some ground water into the house. Usually a gravel base beneath the slab provides a satisfactory capillary break to keep this from being a serious problem. However, sub-slab duct work should be checked regularly to determine that ground water is not seeping through corroded sections of duct.




*Make sure you divert water away from the foundation of the house.*

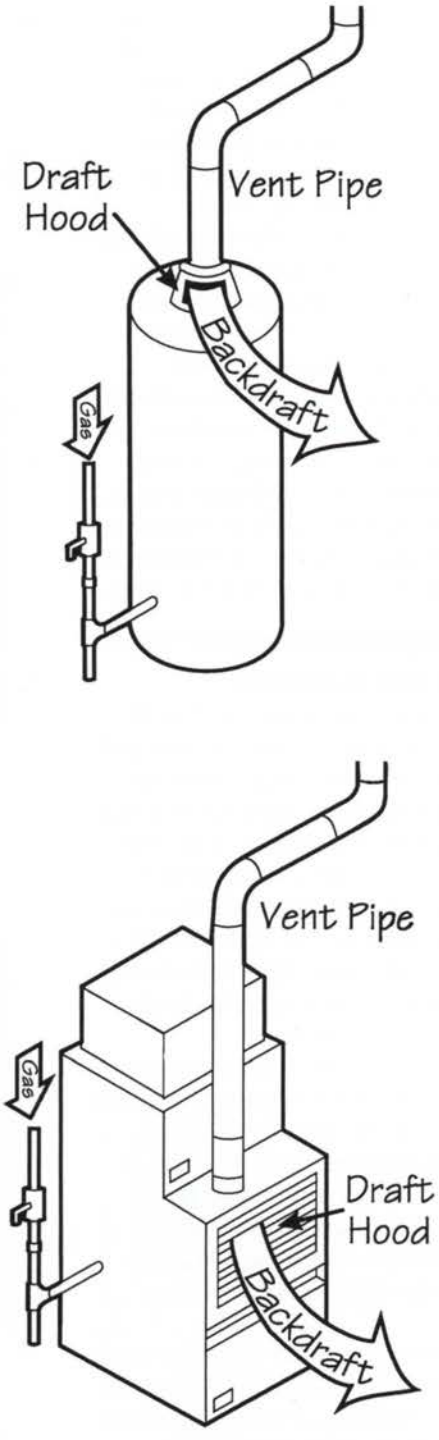
## HUMIDIFIERS AND VAPORIZERS

Humidifiers and vaporizers used to be considered important to our comfort and health. However, their importance has decreased as insulation methods and materials, and protection against leaks has improved. Nevertheless, many homes with forced-air heating systems have mechanical humidifiers. The operation of a humidifier is controlled by a humidistat, which is usually found near the thermostat or in the return air duct.

Humidifiers must be maintained according to the manufacturer's recommendations. This means regular thorough cleaning and occasional recalibration. A dirty humidifier can pose a significant threat to the indoor air quality. Poorly calibrated controls can cause a humidifier to over-humidify, creating serious problems.

If the house shows signs of excess moisture, the humidifier should be turned off. This requires shutting off both the electrical and plumbing connection. The humidifier should only be turned back on if necessary, and then only after cleaning and recalibration.

Some health professionals recommend the use of a vaporizer for certain bronchial conditions. However, any potential health benefits of a vaporizer must be weighed against the disadvantages if the excess water allows the growth of mildew in the humidified room.




***Backdrafting is spillage of combustion gases into the room through the draft hood and can occur in a gas-fired or oil burning water heater, boiler or furnace.***

**COMBUSTION BACKDRAFTING**

Another common source of excess water may come from the use of a combustion appliance. Whenever fuel is burned, by-products, including concentrations of carbon dioxide, carbon monoxide, and water vapor, are generated. All combustion by-products should exit the house through a chimney, flue, or exhaust piping. In standard chimneys, the *stack effect*—hot air rises—drives combustion products up and out. In some furnaces, the stack effect is assisted by a fan.

However, if another strong fan or a fireplace is drawing air out, the air that is supposed to go up and out the chimney may be drawn back into the house. This can occur if a strong fan or fireplace is drawing the air out or if the chimney is blocked, by a bird's nest for example. This is backdrafting, which can cause significant health risks. Several devices are available to check for appliance backdrafting, including carbon monoxide indicators, which are available at most hardware stores.

Chimneys should be checked at least once a year to ensure their safe and effective operation. Flue pipes should be inspected for leaks. Furnaces and boilers should be inspected by reputable service personnel. An exhausting kitchen range hood should be used, especially when the cooking fuel is gas. If a fireplace or appliance smells like a burning product, that is a good indication that backdrafting may be occurring.

**INCIDENTAL MOISTURE SOURCES**

There are several other possible moisture sources that can vary in magnitude.

*These include:*

- construction moisture (in the first year after construction or major remodeling);
- food processing;
- hot tubs, spas, whirlpools, swimming pools, and large aquariums;
- drying firewood indoors;
- clothes drying indoors, or a dryer vented to the indoors; and
- a great number of plants.

In several of these cases it is possible to decrease the moisture problem associated with the source by removing the source, decreasing its use in the home, or by providing ventilation.

**REDUCING MOISTURE BY VENTILATION**

We all require fresh air to live comfortably. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) provides this commonly used standard for house ventilation: 15 cubic feet per minute of fresh air for each occupant, or 35 cubic feet per minute per dwelling unit.

Because we now build tighter houses, we can no longer depend on cracks and other sources of leakage to provide an adequate amount of fresh air. Since the 1960s, most building codes have included a requirement for bathroom and kitchen exhaust fans, which cause outdoor air to filter through any openings.

Consumer complaints about exhaust fan noise have prompted many companies to manufacture fans that are quieter and to provide information about noise levels—measured in sones—on their packaging. Exhaust fans should discharge to the outdoors, not into the attic or crawl space.

In northern areas, use of air-to-air heat exchangers or heat recovery ventilators is growing. These devices are often used in homes with tight construction. They control both the incoming and outgoing air streams and allow the recapture of a portion of the heat that would otherwise be wasted.

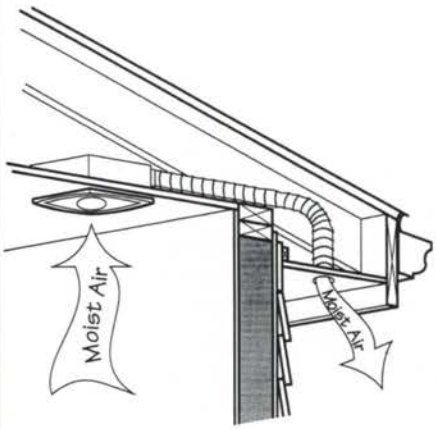
Of course, opening windows remains an excellent way of providing fresh air to the house.

**CONDENSATION**

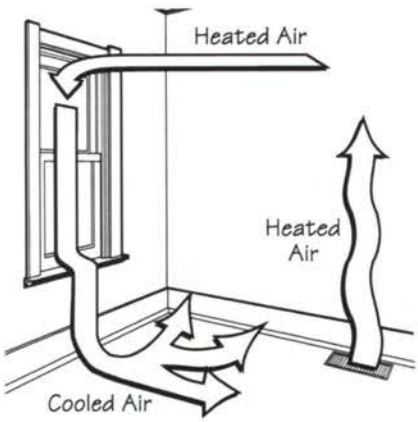
### Windows

Windows are the best indicators of the moisture level in the house. If during the winter the windows have only a light film of condensation or frost, the moisture level is normal.

In two-story houses, condensation is more common on the second floor than on the first floor because air usually enters the house low and exits high, and condensation often occurs where the




*Moist air can be exhausted from the house by a fan. Make sure this air goes completely outside the house and not just into the attic.*




*Heated air will fall down a cold window and spread out over the floor.*

warmed and humidified air is exiting the house.

Houses with storm windows may have condensation either on the storm pane or the inside prime window pane. If condensation occurs on the storm, indoor air is flowing through the cracks in the prime window into the cavity between the two. Condensation may run down the window onto the sill. There should be weep holes between the outside sill and the storm window to let any accumulated water or water vapor escape from the cavity. To prevent condensation on the storm window, tighten the prime window, or enlarge the weep holes to the outside.

Condensation may occur on a double-pane window as well. This usually happens when the frame is cold, or the edge of the thermo-pane is cold. Newer designs of windows and double-pane glass include thermal breaks, which keep the inside surfaces warmer and less likely to cause condensation.

For several decades, it has been commonplace to supply heat to a room from beneath the window. This warms the window surface and reduces condensation potential. It also increases the comfort in the room by preventing cold drafts from forming. If the heat source is away from the window, a drafting convective loop may occur. (See the bottom drawing on this page.) It is always better to locate a heat supply beneath the window.

Drapes and blinds in front of windows often act as insulators, causing the temperature of the glass to be lowered, and increasing the likelihood of condensation. Bay windows are particularly prone to condensation because they are stepped back from any heat supply in the room, and their many corners often allow more air leakage.

## Walls

**W**all condensation can occur on the surface or within the wall cavity. High indoor humidity often causes mold growth on the walls, especially in closets, and behind pictures and furniture, where surface temperature is lower than the rest of the room. To correct the problem, the first step is to identify and remove the source of excess moisture. Then the mold can be washed away with a dilute bleach solution (10 parts of water to 1 part bleach).

Condensation may develop within the building cavity, where it cannot be easily detected. This usually occurs beneath windows, where the moisture source begins as window condensation that drains downward into the wall. It also arises in homes with high indoor humidity at the point where exiting humid air leaks out of the house. One precaution that can be taken is to provide an air seal at electrical openings in the outside walls.

Most homes built since the 1950s have a vapor retarder in the wall. Usually building codes in northern climates continue to require one, and much of the technical literature for building products require one as well. Vapor retarders are designed to reduce the diffusion of moisture into a cavity. Most current research recognizes that vapor diffusion into a cavity is a minor effect compared to the effects of air leakage and indoor humidity levels. Two coats of paint provide a level of protection against the diffusion of moisture that approaches the level of diffusion protection afforded by a membrane vapor retarder.

The exterior of the house may indicate a moisture problem within. Peeling paint is often due to the movement of moisture through siding or cladding products. This condition can often be corrected by inserting painters' wedges between the siding boards. This will allow moisture to escape from between the boards rather than through them. Brick veneer may show signs of efflorescence—the deposit of white salts on the outside surface. This can be prevented by making sure there are no roof leaks behind the brick and that the weep holes at the base of the brick wall remain open and free of debris. The amount of cupping and cracking in wood siding, while a function of moisture, depends more on the thermal and moisture characteristics of the sheathing, which is rarely changed or replaced. Vinyl and aluminum siding seldom exhibit moisture problems.

Mold sometimes grows on the outside surface of a building. This is not related to indoor humidity, but rather to local

conditions of wind and dirt. Exterior mold needs to be cleaned off periodically.

### Ceilings, Attics and Cathedral Ceilings

**W**ater spots on ceilings are very common.

*There are several possible causes, including:*

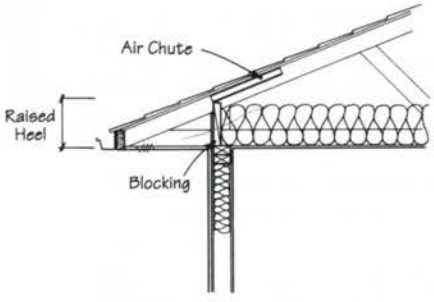
- roof leaks,
- rain or snow leaking through vents,
- ice damming,
- lack of insulation,
- condensate from attic-mounted air conditioner or air conditioning duct work, and
- attic sheathing condensation.

The source of the water can typically be found in the attic. If the spotting is at the outside edge of the ceiling, it is usually due to wind-blown precipitation, ice damming, or to the absence of insulation above the top plate.

Sometimes condensation can be seen on the underside of the attic sheathing. In the worst cases the sheathing can be damaged by mold and delamination. Water that causes this damage has usually traveled from the basement or crawl space through the partition walls to the attic, bypassing the living space entirely. Homes with wet foundations are particularly prone to attic sheathing moisture problems. To solve the problem, it is important to keep the basement or crawl space dry. It may help to block the flow of air through the partitions, particularly at the plumbing stack and duct and flue risers.

Most building codes require the venting of attic spaces, using the 1/300 formula of 1 square foot of vent area for every 300 square feet of attic floor area. Venting has been shown to reduce the likelihood of moisture damage in attics with light to moderate moisture loads, and to maintain the attic and roof at cooler temperatures during the summer. At least half of the vent area should be located in the area of the eaves.

Cathedral ceilings remain a particularly troublesome construction. Most building codes require that cathedral ceiling cavities be vented. Studies have shown that vented cavities (with venting at the ridge and soffit, and a clear air space between the two) work well for maintaining mild temperatures and avoiding moisture problems. Research is currently underway to determine the temperature and moisture performance of unvented cavities stuffed with insulation. Cavities with an airtight ceiling plane are considered quite safe. Vents for cathedral ceilings should be carefully selected to avoid allowing rain or snow to enter.




***A raised heel truss allows a full thickness of insulation at the corner. Use blocking and air chutes to direct the air flow above the insulation.***

### SIDING PROBLEMS

#### Peeling

Paint peeling and blistering may result when water within the wall migrates outward during cold weather. Characteristically, the blisters will contain water and the paint peels down to the bare wood. Poor paint, faulty application of paint, and exterior moisture also cause paint problems, but are not within the scope of this circular.

Paint peeling on wood siding can be reduced by making sure that the siding forms a screen that keeps the rain out, but does not trap air or moisture behind it. The joints between siding boards should remain open, so that water can escape, and high vapor pressures can be reduced. Painter's wedges are often used to maintain a gap between siding boards.

#### Mildew

Mildew often appears on siding and trim as small black spots. It can be washed off with a dilute (10:1) solution of water and bleach.

Mildew grows on dirt lodged within the microstructure of the exterior finish. Changing the indoor humidity condition will have no effect on the growth of exterior mildew.

Paint stores sell a mildicide that can be added to paint and stain. These mildicides are safe and effective, but their effectiveness diminishes over time and the mildew can return. Cleaning and maintenance are the only solutions.

## Moisture Condensation Checklist

| PROBLEM | DUE TO | SOLUTION |
|---|---|---|
| Ceiling spotting | Roof leaks<br>Ice damming<br>A/C condensate<br>Cathedral ceiling penetrations (recessed light fixtures, exhaust fans)<br>Duct condensation (cooling season)<br>Wind-blown precipitation through vents and louvers<br>Uninsulated (cold) spots<br>Plumbing condensation | Roof repairs<br>Roof ventilation<br>Clear condensate line, install backup pan<br>Install fixtures designed for air-tight installation, good workmanship<br>Re-wrap ducts with insulation and vapor retarder<br>Select vent design for water exclusion<br>Add insulation to bare spots<br>Gasket between vent pipe and top plate |
| Roof leaks | Workmanship, products | Roof repair |
| Damp ceilings at edges near outside wall | Incorrect insulation installation | Reposition insulation, install air chutes and blocking |
| Mold on walls (heating season) | High indoor humidity | Find and remove excess moisture source, clean with dilute bleach solution |
| Mold on walls (cooling season) | Cold side vapor retarder | Use vapor permeable interior finish, avoid depressurization of interior |
| Damp exterior walls | Settled insulation, ice dam leakage | Correct insulation, install eave flashing |
| Window condensation | High indoor humidity | Find and remove excess moisture source, place heat source beneath window, open drapes and blinds |
| Frost or ice on window glass | Single glazing | Use double glazing, install storm windows |
| Moisture dripping from light fixtures, heating/cooling registers | Fixtures or registers are cold metal | Make sure insulation covers duck work, avoid recessed fixtures |
| Mold or decay on floor framing | High humidity in basement or crawl space | Place ground cover in crawl space, correct site drainage |
| Roof sheathing: frosting mold, delamination | High humidity in attic | Close holes in ceiling plane, add balanced ventilation |
| Exterior paint peeling | Moisture transport to outside | Reduce interior moisture level, allow moisture to escape behind siding |
| Mildew on exterior walls | Natural conditions | Remove by scrubbing, repaint with mildicide-containing paint |
| Mildew on interior walls or in closets | No heat source or inadequate air circulation | Add insulation, install louvered doors, reduce humidity |
| Mildew on bathroom tile, grout and shower curtains | High bathroom humidity | Remove mildew, use exhaust ventilation |
| Water in basement/ crawl space | Site damage<br>Plumbing leaks<br>A/C condensate<br>Rising water table | Correct gutters, downspouts, drainage<br>Repair plumbing<br>Drain to outside<br>Sump pump, consult geotechnical engineer |
| Truss rise | Wood characteristics and truss geometry | Fasten edge of ceiling panels to partition, not truss chord |
| Moisture/frost near edge of concrete floor slab | Not correctly insulated | Place insulation on outside of slab |
| Efflorescence on masonry & concrete | Moisture movement through materials | Reduce leak or moisture source |
| Mold on framing or trim at windows | Window condensation | Reduce high humidity or locate heat source near window |

## Basements and Crawl Spaces

The foundation area of a house may be the site of moisture damage. Mold may grow on basement walls, and is often seen in corners where downspouts deposit water into the soil adjacent to the foundation. If water is allowed to stand in the basement or crawl space for a long time, the floor framing above may be affected.

Crawl spaces, in particular, may be prone to damage from moisture. Every crawl space should be inspected seasonally and after every big rain.

*Crawl spaces should be inspected for the following conditions:*

- exposed soil with no ground cover,
- puddling of water on top of the ground cover,
- plumbing leaks or leaks of air conditioning condensate, and
- mold growth or fungal attack of the floor framing, particularly at the outside perimeter.

If any of these conditions develop, the source of the water should be removed, and the condition corrected. Mold can be removed from floor framing using a dilute bleach solution. Joists can be tested for soundness using an ice pick. Softened joists should be reinforced or "sistered"—adding another joist along side.

Objects should not be stored on the ground cover in areas where the water table is high. The cover should be kept free of all debris in these areas, so it will float above any water that rises into the crawl space.

If the crawl space is known to be dry, its vents can be closed, and the foundation walls and band joist area insulated. See the drawing on page 3, showing crawl space detail, and Building Research Council circulars F2.0—*Basement Construction* and F4.4—*Crawl Space Houses*.



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